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TECHNICAL REPORT ARLCD-TR-79029

## INDIRECT FIRE ARTILLERY GROUND-BURST SIMULATOR

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND  
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An exploratory development effort was conducted to design, fabricate, and test an experimental breadboard artillery ground burst simulator (AGBS) for use in two-sided tactical training exercises. The AGBS was successfully demonstrated during a REALTRAIN training exercise at Fort Carson, Colorado, 22 March 1978.		

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## SUMMARY

This report analyzes the development of a new prototype pyrotechnic device, an indirect fire Artillery Ground Bust Simulator (AGBS). The device is intended to simulate the visual and audio burst effects of an artillery round as a warning to personnel under fire and as a spotting aid for forward observers.

The program resulted in a prototype design consisting of a modified M583A1 40 mm grenade round which ejects a payload (6-second delay) at the height of its trajectory. The payload hits the ground in the target area, whistles for 3 seconds and explodes. Existing 40 mm hardware, used to keep costs down, also permitted the use of the M79 and M203 grenade launchers.

Development of the prototype design started in September of 1977, but in order to satisfy the requirement for a concept feasibility test during training exercises at Ft. Carson, Colorado, in March 1978, the design had to be frozen in December 1977.

Although the original design met the Circular Error Probable (CEP) accuracy requirement of 25 meters at maximum range, the round indicated a basic instability, especially at the higher firing angle ( $70^{\circ}$ ,  $80^{\circ}$ ). Thus, most of the effort of the program was expended in improving the stability of the round within the constraints of the existing hardware. This effort included computer analysis, wind tunnel tests, and test firings. Although these efforts did not completely correct the instability problem, the round was considered acceptable for the concept feasibility test.

There was also concern over the hazards involved in firing the AGBS over the heads of troops and into areas where troops were deployed. Such concern included injuries from the payload, the projectile, and duds (rounds which do not separate).

Therefore, further analyses were performed, considering all variables involved, and the results indicated that the round was safe for use as intended in the concept feasibility test provided that designated safety procedures were followed.

Fragmentation tests were also conducted which indicated that there is no fragmentation hazard to personnel from the payload.

Additional studies were performed which revealed that the M115 composition produced the most realistic sound level and smoke cloud and, therefore, was used for the concept feasibility test.

Since this is the first simulator to be fired over and into the areas of friendly troops, much effort and thought had to be put into the safety of the item which culminated in the acceptance by the Army Surgeon General's Office of the Interim Safety Statement. Their acceptance permitted the AGBS round to be used on a limited scale during the March 1978 REALTRAIN test at Ft. Carson, Colorado, with no reported injuries.

A review of the concept feasibility test was held at PM TRADE Field Office, Ft. Eustis, Virginia. The range, smoke signature, and accuracy at maximum range were all acceptable at this test; however, a number of areas were identified which require additional development. These areas include reducing the minimum range, increasing accuracy at higher quadrant firing angles, lowering the dud rates, and reducing the number of grass fires.

The Ft. Carson test indicates that the concept of a launchable artillery ground burst simulator could provide combat and artillery personnel with realistic battlefield conditions, and also meet the Surgeon General's Standards of Safety.

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## BACKGROUND

The indirect fire Artillery Ground Burst Simulator (AGBS) is being developed for use primarily in tactical engagement simulation exercises. These two-sided, free-play tactical exercises provide a training system which will allow combat units from squad to battalion level to train as they will fight. The training system consists of equipping each side with devices which realistically simulate its weapon systems, a method of real-time casualty assessment, and a means of gathering battle information in order to reconstruct the battle for a post action review.

Currently the Army is using a training system called REALTRAIN. This system allows units up to platoon level to participate in tactical engagement simulation exercises. Simply, REALTRAIN uses a system of low-power telescopes, identification numbers, and a radio-linked control net to accomplish the training system described above.

To allow units of company and battalion size to participate in tactical engagement exercises, the multiple integrated laser engagement system (MILES) is being developed. MILES simply equips each direct-fire weapon on the battlefield with a low power, eye safe, laser transmitter. Coupled with vehicular and man-worn laser detectors, automatic casualty assessment is possible.

To further the training value of tactical engagement simulation exercises, each direct-fire weapon is equipped with a signature device which simulates the visual and aural effect of the weapon's firing. Unfortunately, the simulation of indirect fire on the battlefield has not progressed to the degree of direct-fire weapons. The current M115 ground burst simulator, hand thrown, is used to simulate indirect fire.

In REALTRAIN exercises, the forward observer calls for fire on a target. The fire control center then directs a jeep-mounted fire marker to the target area where he detonates an M115 simulator. Subsequent adjustments and fire-for-effect are accomplished in the same manner. This system is highly undesirable for the following reasons:

1. The target has an unrealistic warning of forthcoming indirect fire.

2. The number of vehicles and personnel involved is excessive (for REALTRAIN at platoon level, three jeeps, six personnel, and six radios are required).

3. The time to deliver a fire mission, once requested, is excessive and unrealistic.

To alleviate these problems and most importantly, to increase training effectiveness through realism, the development of an improved artillery simulator was authorized by the office of the Project Manager for Devices (PM TRADE), Ft. Eustis, Virginia. On 13 July 1977, PM TRADE tasked ARRADCOM to design, fabricate, test, and evaluate a prototype design for a new artillery ground-burst simulator. The following performance parameters were provided to ARRADCOM by PM TRADE as requirements:

1. Troop safety; zero probability of death for a direct hit on a man wearing only fatigue uniform with steel helmet at any range between 30 and 300 meters. Assume no firing angle less than 40° elevation will be used.

2. Orange flash.

3. Black-gray smoke cloud 3 to 5 meters in diameter for a minimum of 3 seconds duration.

4. Circular Error Probable (CEP) of 25 meters radius at maximum range.

5. Over-pressure of 135 db minimum and 140 db maximum at 25 meters.

6. Single ground-burst initiation  $3 \pm 1$  seconds after impact preceded by a 3-second warning whistle not to exceed 120 db, 1 foot from the source.

7. Range minimum of  $30 \pm 10$  meters; maximum,  $300 \pm 100$  meters.

8. Limited flame generation and outer shell composed of fire retardant material to reduce incendiary effect.

9. Zero probability of death from fragmentation or burn effects.

## DISCUSSION

### Prototype Design

Based on PM TRADE's requirements, ARRADCOM initiated the development of prototype design (figs. 1 and 2) with the following physical characteristics:

#### Prototype Ground-Burst Simulator

Length (max)	5.27 in.
Weight (avg)	184 g
Diameters (max)	1.72 in.

#### Cartridge Case M195

Length (max)	1.89 in.
Weight (loaded)	45 g
Primer M42	Percussion
Propellant M9	365 milligrams

#### Projectile

Length (max)	4.36 in.
Weight (avg)	139 g

#### Pyrotechnic Payload

Length (avg)	2.7 in.
Weight (avg)	50 g
Diameter (avg)	1.4 in.
Flash and smoke charge (avg)	20 g

Magnesium	34%
Aluminum	26%
Potassium perchlorate	40%

Delay charge (avg)	3 g
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Black powder	80%
Calcium carbonate	10%
Polyvinyl acetate	10%

Whistle charge (avg) 2 g

Sodium salicylate	28%
Potassium perchlorate	69%
Red gum	3%

The simulator is ready for use as issued and requires no preparation prior to loading into the launcher. The AGBS is loaded into the M203 grenade launcher which is fired at an angle of 40° to 80°. Upon firing, the M42 primer ignites the M9 propellant which ejects the projectile from the launcher and also ignites the delay in the projectile. After approximately 6 seconds, the delay ignites the ignition/ejection charge to expel the payload. The iron filings located in the cap are dispersed in the atmosphere and the aluminum carrier falls to the ground. The payload continues down range to impact at ranges up to 290 meters (depending on the firing angle). The payload's delay, ignited at ejection, ignites the whistle composition which emits a 3-second warning whistle. The whistle composition in turn ignites the smoke and flash charge emitting a loud noise, flash, and smoke cloud.

#### Concept Evaluation

In consideration of troop safety, a preliminary safety assessment was conducted on the 40 mm signal projectile. The results indicated that within current parameters, a projectile weight of 160 grams impacting at 150 ft/sec is potentially unsafe and may inflict a lethal wound due to blunt trauma. To avoid this hazard, two concepts were evaluated. One involved the use of a "collapsible" nose to reduce the energy at impact to an acceptable level. A second concept involved delivery of a relatively lightweight (50 gram), free falling sub-missile (payload) to the target area. Variations to this latter concept involved the use of a drag device (ribbon or loop) attached to the sub-missile. Five rounds each of the four designs (collapsible nose, free falling sub-missile, ribbon retarded sub-missile, and loop retarded sub-missile) were fabricated and tested at Longhorn Army Ammunition Plant the week of 15 August 1977.

Based on the results of the Longhorn Test, the free falling sub-missile concept was found to be the most promising and was selected for further evaluation. The use of a drag device was abandoned since it reduces the range and covertedness of the item. It was further reasoned that the presence of a drag device would degrade accuracy by making the round more susceptible to wind conditions. The collapsible nose concept was discontinued due to unstable flight, and the round tumbled and impacted on the base.

The selected design consists of a cartridge case, a one-piece aluminum projectile, a pyrotechnic paper payload, and a plastic snap-on ogive. The payload consists of a paper container housing, a 25 gram loose black-powder charge, and a delay and whistle assembly. To improve stability during flight, 30 grams of iron filings were added to the ogive cavity. A test firing of five rounds at 45° elevation and a range of 290 meters resulted in a Circular Error Probable (CEP) of less than 1 meter.

#### INITIAL DEMONSTRATION

Once a prototype design was decided upon, an initial demonstration was conducted at Ft. Sill, Oklahoma, to evaluate the design. Attendees included representatives from the U.S. Army Field Artillery School, U.S. Army Training Support Center, PM TRADE, Army Research Institute, ARRAADCOM and Thiokol/Longhorn Army Ammunition Plant. Follow-up discussions addressed the safety and utility of the design and resulted in the following comments:

1. The smoke cloud produced by black powder was considered inadequate.
2. The dispersion of ground impacts at mid-ranges (high QE) was considered excessive. It was recommended that the stability of the projectile should be improved.
3. The excessive amount of flame produced by the whistle composition was considered to be the prime cause of the ground fires. It was recommended that effort be directed to modify the whistle assembly to correct the problem.
4. Quantitative data should be generated to establish the extent of injuries to ground personnel if struck by the payload or projectile body.
5. Present configuration concept is promising enough to continue development.

#### Stability Studies

Test firings and wind tunnel tests were conducted to identify the problem and correct the stability of the AGBS prototype design. These tests revealed a flight stability problem after the round left the launcher which caused erratic payload dispersion, especially at high firing angles (70°, 80°).



Initially, due to this instability, the weight of the iron filings in the ogive was increased from 30 grams to 40 grams to move the center of gravity (CG) toward the center of pressure (CP) of the projectile. It was thought that this would decrease the yaw. However, after firing several rounds of the heavier configuration, it was apparent that this "fix" did not improve the flight. Once this was apparent, a change in the ogive shape to a blunt nose configuration was considered.

This change in shape moves the CP toward the CG in an attempt to stabilize the round. To verify this concept, a total of 30 rounds were fired from the M203 launcher, 10 rounds each at firing angles of 40, 50, and 60 degrees. The impact points of the rounds were staked and the ranges, dispersions, and CEP were determined (table 1). The average range of these blunt nose rounds, at a firing angle of 40 degrees, was 250 meters, which is 40 meters less than the rounded ogive configuration. All CEP's at firing angles of 40, 50, and 60 degrees met the requirement of a CEP of 25 meters with CEP's of 16.5, 17.3, and 18.2 meters, respectively. However, through visual observations, the flights of these blunt nose rounds were unstable. Further testing was conducted to determine if this shape were better than the rounded ogive relative to stability, deflection, and range.

After analyzing the test data, it was decided that the rounded ogive with 30 grams of iron filings in the nose would be used in the concept feasibility test. The rounded nose was selected because of the 288-meter average range vs. the 210-meter average range of the blunt nose shape (table 4).

No improvement was noticed in stability or deflection with either a change in weight or in the shape of the nose. These problems will have to be addressed in the advance development program.

#### Signature of the Round

The original payload consisted primarily of black powder. The size and density of the smoke cloud and the noise level of the burst were considered inadequate.

The M115 composition was next tested and produced a superior band and smoke cloud. However, the white cloud produced by the M115 mixture was not considered realistic since the smoke cloud from a bursting artillery shell is dark gray.



Effort was directed during the program to investigate various ingredients which, when added to the existing composition, will produce a darker smoke cloud. Several mixtures of anthracene with black powder and photoflash (M115 mixture) were tried, but no acceptable smoke could be generated.

It was decided that the smoke, color, size and blast effect of the M115 mixture would be adequate for this prototype program and should be used.

#### Range Fires

During testing of the AGBS an excessive number of range fires were started by the simulator. By visual observation, it was determined that the whistle/delay assembly started most of the range fires.

A development effort was therefore started to eliminate the fire hazard from the delay and whistle assembly in the payload. Two concepts were investigated. One involved the use of a mechanical device powered by a gas generating propellant to produce a whistle sound. The second attempted to suppress the emission of flame from the present delay whistle assembly by means of baffles. Initial tests indicated that a reliable mechanical whistle was unattainable and the concept was abandoned. Attempts to suppress the flame by baffles showed some promise, but the data are too limited to be conclusive. Additional design and test efforts would be required before the utility of the concept can be properly assessed. In view of the time constraints, a workable design for the Ft. Carson test did not appear feasible; therefore, this concept was also abandoned for use in the concept feasibility test.

Initially, it was thought that the range fires were due to the whistle/delay assembly. However, during the concept feasibility test it was revealed that other parts of the payload might also cause these fires. In order to determine the responsible payload components, testing was conducted at Longhorn in which the following items were fired:

1. Five payloads with the M115 composition.
2. Five payloads minus the delay/whistle assembly with the M115 composition.
3. Five payloads minus the delay/whistle assembly with black powder.

4. Five delay/whistle assemblies with whistle composition only.

5. Five delay/whistle assemblies with delay composition only.

All payloads and delay/whistle assemblies were initiated electrically in a bed of hay. These tests were set-up for the worst possible conditions, therefore, more fires should be started than normally. One fire was started from M115 composition; three from the whistle composition, and one by the delay assembly.

It was therefore concluded that all of the components of the payload started fires but the majority were started by the delay/whistle assembly. Consequently, studies were conducted on the whistle composition to find possible formulations which would provide the required duration of whistle (3 seconds  $\pm$  1 second) but, unlike the current whistle, would not spew hot particulates and flame. The following formulations were investigated:<sup>1</sup>

1. 72.5 - 24.5 - 3.0  $\text{KClO}_4$  - NaSal - Red Gum
2. 69.0 - 28.0 - 3.0  $\text{KClO}_4$  - NaSal - Red Gum (dwg control)
3. 80.0 - 17.0 - 3.0  $\text{KClO}_4$  - NaSal - Red Gum
4. 72.0 - 27.0 - 1.0  $\text{KClO}_4$  - Hexamine - VAAR
5. 68.0 - 32.0 - 10.0 -  $\text{KClO}_4$  - Hexamine -  $\text{KHCO}_3$  - VAAR
6. 70.5 - 29.5 - 5.0 - 1.0 -  $\text{KClO}_4$  - Hexamine  $\text{KHCO}_3$  - VAAR

The current composition (no. 2, above) was included for purposes of comparison. It is fuel-rich, a possible cause for the expulsion of hot particulates. Composition no. 1 makes use of the same constituents but in stoichiometric proportion. Composition no. 3 is an oxidant-rich mixture of these materials. Composition nos. 4, 5, and 6 have been used in connection with another program and had demonstrated minimal hot particulate spew.

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<sup>1</sup>VAAR - Vinyl Alcohol Acetate Resin  
NaSal - Sodium Salicylate  
 $\text{KClO}_4$  - Potassium Perchlorate  
 $\text{KHCO}_3$  - Potassium Bicarbonate

Upon ignition of the consolidation composition, the following data and information were recorded:

<u>Compositions numbers</u>	<u>Burn time (sec)</u>	<u>Notes</u>
1	2.7	Somewhat less spew
2	2.7	Considerable hot particulate spew
3	2.0	Somewhat less spew
4	16.0	Small flame, no spew
5	no ignition	
6	2.3	Small flame, no spew

Of all the compositions, only no. 2 provided the desired whistle effect. This is the current composition. Further studies are therefore needed to find composition that gives the desired whistle effect without spewing out hot particulates.

#### Impact Velocities and Trajectories

A computer study to determine impact velocities and trajectories at various firing angles and delay times from firing to burst for both blunt nose and rounded ogive configurations was conducted. Impact velocities, time of flight, and range for the projectile body and the payload are listed in tables 5, 6, and 7. Trajectories for 40 and 80 degrees for 6 to 8 seconds delay are shown in figure 3. At a 6-second delay the computed impact velocity for 40, 50, 60, 70, and 80 degrees are 113 ft/sec, 110 ft/sec, 111 ft/sec, 113 ft/sec, and 114 ft/sec, respectively. These data were used in the blunt trauma assessment. To confirm the calculated values, impact velocities were also measured by radar. The measured values for 40, 50, and 80 degrees are 122 ft/sec, 127 ft/sec, and 115 ft/sec, respectively (table 8). Based on these measured values the calculated values are considered a good estimate of the impact velocities (table 8).

## Blunt Trauma Analysis

The AGBS is a training device fired into areas of friendly troops. Therefore, an analysis and evaluation of the AGBS round was required concerning the possibility of some major part of the AGBS hitting a soldier during its down range flight.

When a projectile hits someone, injury or death may occur by blunt trauma. Therefore, a series of blunt trauma analytical calculations were made on the AGBS using the physical properties of the item. (These calculations and other test data are contained in the appendix.) The lethality of the projectile was first considered. Results indicated that there is no blunt trauma hazard from the payload or aluminum body at current impact velocities. It was determined that an impact velocity of 150 ft/sec would be needed before the payload or the projectile body becomes a lethal hazard. However, a dud projectile at a weight of 140 grams would present a blunt trauma hazard which could inflict a lethal wound. In view of the low dud rate history for the present delay configuration (40 mm projectile) combined with all other factors (i.e., a number of rounds fired, density of troops in area, etc.) the probability of a lethal hit from the AGBS is considered to be almost negligible.

Another blunt trauma analysis was performed on the probability of being struck by either a payload or aluminum body down range which might cause injury. This analysis was based on the following assumptions: 100 rounds being fired, a full battlefields (2 kilometers x 5 kilometers area) and three troops per 25 meters CEP. The analysis also considered that the battlefield size and number of personnel changes as the battle progresses.

The following is the probability of being struck under different battlefield and troop conditions.

1. Full battlefield and 120 troops - 0.000360
2. 1/2 battlefield and 108 troops - 0.000647
3. 1/8 battlefield and 60 troops - 0.001434

Based on these analyses the AGBS was considered safe for use in the concept feasibility test provided that appropriate personnel protective equipment and safety procedures were used (appendix D).

## Fragmentation Test

A fragmentation test was conducted to determine the penetration properties of the payload. Five payloads of the AGBS were ignited inside a 4-foot cube of 1/2-inch-thick celotex witness panels (figs. 4, 5, and 6). The resultant debris consisted essentially of pressed cardboard fragments of no penetrating quality (figs. 10 and 11).

The only instance of panel penetration was from the delay whistle tube (figs. 7 and 8). This tube is a lighter version of the M15 whistle tube which weighs 6 grams. The M15 tube assembly weighs 12 grams and has never been reported as presenting a fragmentation hazard. Further, there is prior experimental evidence that 20 grams of a plastic like material is required to cause skin penetration. It is therefore felt that there is no fragmentation hazard from this simulator.

## Noise and Toxicity Tests

In addition to the blunt trauma and fragmentation tests, several other tests and analyses were performed to determine the hazard of the round. A noise hazard analysis was performed by the Army Environmental Hygiene Agency based on data obtained at Longhorn Army Ammunition Plant which shows a db level in excess of 140 dba at 25 meters or less (table 9). As noted in the report, detonation within a few meters of personnel (worst possible case) could produce some permanent hearing damage. It was therefore recommended that personnel involved in field exercises using the AGBS wear protective hearing devices. This information was added as a supplement to the Safety Statement.

A toxicity hazard analysis of the AGBS payload and whistle composition was also completed by the Army Environmental Hygiene Agency, Chemical Systems Laboratory. The analysis indicated that no significant inhalation or skin contact exposure hazard would be produced if specific procedures (outlined for CSL) were observed. Therefore, toxicity is not a hazard from the AGBS.

## Launcher Mounts

The AGBS was fired from the M203 grenade launcher. The lowest firing angle of the launcher should be limited to 40°. However, during training exercises there is the possibility that someone may fire the launcher inadvertently at a lower angle when personnel are directly in front of the weapon. A mechanical device, the launcher

mount, was therefore developed to prevent the launcher from being fired at an angle of less than  $40^{\circ}$ .

The launcher mount is secured in the rear of an M151 jeep by use of post clamps to avoid a permanent modification to the vehicle. Stops on the post limit traverse so that the launcher can only be fired 180 degrees (centered rearward) in azimuth. This was done to prevent any possible injury to the driver of the jeep. Elevation was limited to a minimum of 40 and a maximum of 80 degrees. An angle-measuring device to indicate elevation is placed on the left of the mount. An automobile compass is behind the mount to measure direction. This compass can be adjusted to compensate for the metal in the vehicle (fig. 12). Five of these launch mounts were shipped to Ft. Carson for use in the concept feasibility test. The following comments were made on the launcher mounts:

1. The compass should be taken off the mount. As presently mounted, it receives the full shock of recoil. The compass mount is very fragile and cannot take extensive high speed cross country travel.

2. The angle indicator should be made of more rugged material. The current one is a carpenter's measure and probably would not withstand field use.

3. All removable parts of the launcher mounts should be secured to withstand field use.

#### Concept Feasibility Test

Two thousand rounds of the AGBS and five launcher mounts were manufactured at Longhorn AAP for concept feasibility testing Ft. Carson.

On 2 March 1978, a production sample of 88 rounds were removed from the lot and test fired.

A 3% projectile dud rate in this lot was attributed to improper consolidation of the delay. After screening and re-working the delays, another 88 rounds were test fired. There were no projectile duds in this sample; however, there was a payload dud rate of approximately 5%. Normally, this payload dud rate would not have been acceptable. However, since additional rounds were scheduled to be used during the REALTRAIN exercises starting the following week, it was decided to ship the remaining rounds from LAAP to Ft. Carson for further testing.



On 15 March, 22 rounds were fired at Ft. Carson as a concept demonstration for Army personnel. During the next two days 134 rounds were fired to obtain data to develop a range and dispersion table (table 10). These firings also revealed a high payload dud rate. The payload ejected properly from the projectile, but the delay and whistle assembly failed to ignite.

Disassembly of a number of rounds revealed that the black powder igniter on the end of the delay and whistle assembly was not igniting the delay composition.

Two hundred and twenty rounds were re-worked by removing most of the black powder igniter. This was done to ignite the delay composition directly to see if this would decrease the dud rate. The payloads on the 220 rounds were also painted orange for easier location in the field in case of a payload dud.

On the 20th and 21st of March, 104 of the unmodified and 130 of the modified rounds were fired with dud rates of 15% and 8%, respectively (table 11).

On 22 March, 50 of the modified rounds were fired into the test area containing troops, with no injury reported. Four out of the 50 rounds were payload duds, with all the rounds landing in the general area of the troops.

After the test was completed, questionnaires were given to the troops participating in the exercise to obtain their reaction to the user of the AGBS. A commercial firm, Human Sciences Research, Inc., of McLean, Virginia, was tasked to analyse the questionnaires and distribute their summaries. The results indicated that the simulator was well received by the troops and served its intended purpose of simulating an artillery ground burst.

#### Program Review

A program review was held on the Artillery Ground Burst Simulator at PM TRADE Field Office, Ft. Eustis, Virginia, with the following participating organization: Army Field Artillery School, Army Training Support Center, PM TRADE, Thiokol/Longhorn, Human Sciences Research, Inc., and ARRADCOM, Dover, NJ. The following recommendations were made:

1. Reduce the projectile and payload dud rates.
2. Re-design payload components to eliminate fires in the test areas.

3. Use flame retardant materials.

4. The round should be capable of being used at ranges of 100 meters to 300 meters to avoid moving the M203 grenade launcher when the target area is changed from 300 meters to 100 meters.

5. The grenade launcher mount should have markings for various firing angles

6. The Ft. Carson test indicates that the concept of a launchable artillery simulator could provide an adequate cue for artillery, provide realistic battlefield conditions with troop acceptance and, at the same time, be acceptable to the Surgeon General relative to Standards of Safety.

### CONCLUSIONS

The demonstration of the prototype AGBS design generally satisfied the requirements for troop safety, maximum range, and realism. It is therefore considered to be an acceptable approach to the development of an indirect-fire ground burst simulator.

However, the test program identified the following problem areas where additional research and development are needed before an acceptable design can be achieved:

1. Excessive number of ground fires from the payload assembly when fired into dry grass.

2. Flight instability resulting in excessive payload dispersions, particularly at high elevation (short range) firings.

3. Smoke cloud color. Although the density and size of the cloud produced by the payload were considered to be satisfactory, greater realism dictates a darker cloud.

4. Shorter minimum range. The round should be capable of being fired between 100 meters and 300 meters to eliminate the need to move the M203 grenade launcher when the target area is changed from 300 meters to 100 meters.

5. The high payload dud rate. The high payload dud rate encountered during the Ft. Carson exercise is considered to be a Quality Assurance problem and not indicative of a defect in design.



These problem areas will all be addressed during the Advanced Development Program.

Table 1. Longhorn test of artillery ground burst simulators

<u>Firing angle</u> (degrees)	<u>Range</u> (meters)	<u>Dispersion</u> (meters)
40	214	3 R
40	209	10 L
40	228	8 L
40	232	3 R
40	139	4.5 R
40	267	1 R
40	248	3.6 R
40	214	7 R

Avg range  $\bar{R}$  - 229 meters, avg dispersion  $\bar{X}$  - 5 R, CEP - 16.5

50	176	1 L
50	202	16 R
50	211	14 R
50	181	7 R
50	162	20 R
50	227	25 R
50	160	11 R
50	192	0
50	171	1 L
50	182	15 R

Avg range  $\bar{R}$  - 186 meters, avg dispersion  $\bar{X}$  - 11 R, CEP - 17.3

60	157	10 R
60	156	6 R
60	158	18 R
60	207	0 R
60	145	20 R
60	145	8 R
60	168	6 R
60	133	20 R
60	145	3 R
60	176	5 L

Avg range  $\bar{R}$  - 159 meters, avg dispersion  $\bar{X}$  - 8 R, CEP - 18.2

NOTE: R and L signifies right and left of a theoretical vertical firing line.

Table 2. AGBS design testing at 40°

Firing no.	Round no.	Ejection time (sec.)	Time to ground (sec.)	Time to whistle start (sec.)	Time to blast (sec.)	Weight in nose	Range (meters)	Deflection* (meters)
1	1	5.16	7.30	18.44	20.45	10	235	31 R
2	2	6.21	9.30	—	19.64	10	313	32 R
3	3	6.36	8.38	17.84	19.84	10	250	26 R
4	4	7.08	7.74	22.63	24.29	10	225	24 R
5	5	4.94	8.27	17.14	18.82	10	248	37 R
6	11	4.96	9.56	19.52	20.26	20	241	32 R
7	12	6.21	7.84	—	—	20	278	29 R
8	13	5.24	8.07	17.59	21.13	20	217	28 R
9	14	5.29	7.54	18.93	22.19	20	240	33 R
10	15	6.27	7.38	21.24	24.23	20	253	22 R
11	21	4.63	9.51	16.98	18.84	30	313	57 R
12	22	4.92	7.85	18.84	22.49	30	277	26 R
13	23	5.86	8.22	17.99	20.66	30	261	31 R
14	24	5.24	—	16.68	19.05	30	223	16 R
15	25	4.96	7.41	20.64	21.53	30	276	31 R
16	31	4.89	9.84	17.83	21.19	40	301	23 R
17	32	4.67	8.64	—	—	40	296	22 R
18	33	5.97	9.66	17.51	19.50	40	327	24 R
19	34	4.83	7.60	18.09	19.66	40	284	22 R
20	35	5.38	7.61	17.37	21.56	40	277	17 R
21	41	4.94	9.36	17.70	20.06	50	319	22 R
22	42	5.42	6.91	20.92	22.65	50	193	3 R
23	43	5.28	8.25	24.66	26.67	50	193	6 L
24	44	5.48	—	21.13	22.11	50	293	24 R
25	45	5.64	7.32	20.10	22.30	50	178	21 L
26	51	6.64	—	18.89	21.14	60	218	4 R
27	52	5.69	9.07	20.03	—	60	280	24 R
28	53	4.74	6.01	—	—	60	170	10 L
29	54	5.14	7.76	20.21	21.97	60	224	0
30	55	4.73	7.14	—	—	60	171	6 L
31	61	5.25	7.65	18.83	20.55	0	225	11 R
32	62	4.66	7.70	18.50	20.04	0	236	14 R
33	63	4.52	8.61	19.32	20.21	0	262	18 R
34	64	4.78	8.94	20.63	21.92	0	269	30 R
35	65	5.20	7.94	17.22	18.09	0	249	17 R

\*R = right and L = left.

Table 3. AGBS design testing at 70°

Firing no.	Round no.	Ejection time (sec.)	Time to ground (sec.)	Time to whistle start (sec.)	Time to blast (sec.)	Weight in nose	Range (meters)	Deflection* (meters)
1	6	5.24	12.45	16.88	18.83	10	209	17 R
2	7	5.51	—	20.56	21.93	10	181	11 R
3	8	5.30	14.86	16.61	—	10	192	11 R
4	9	5.03	—	19.24	20.76	10	119	34 L
5	10	—	dud	—	—	10	116	20 L
6	16	6.43	13.27	16.58	19.22	20	192	5 L
7	17	5.03	13.91	22.44	23.06	20	198	5 R
8	18	5.60	13.42	20.67	20.88	20	189	6 L
9	19	5.46	13.40	19.38	20.94	20	189	22 L
10	20	5.04	14.72	19.93	21.77	20	178	28 L
11	26	5.71	11.89	20.93	23.81	30	175	3 L
12	27	5.24	11.92	17.96	20.30	30	122	8 L
13	28	4.65	11.66	17.24	19.58	30	147	10 L
14	29	—	dud	in	gun	30	dud	—
15	30	4.70	11.13	19.88	22.53	30	125	6 L
16	36	6.16	10.35	20.55	22.24	40	134	24 L
17	37	5.46	15.49	19.56	22.26	40	229	10 L
18	38	5.20	—	21.61	23.19	40	132	39 L
19	39	6.36	10.81	22.03	24.22	40	115	14 L
20	40	5.82	11.94	17.94	20.28	40	156	10 L
21	46	5.25	10.71	20.41	23.25	50	96	12 L
22	47	5.45	13.70	14.93	17.85	50	174	7 L
23	48	4.69	12.13	20.16	22.20	50	162	6 L
24	49	5.12	13.07	22.24	26.04	50	184	17 L
25	50	6.38	13.41	22.08	24.21	50	193	12 L
26	56	6.54	13.47	18.35	21.58	60	196	20 L
27	57	5.85	13.22	—	—	60	181	25 L
28	58	5.27	—	19.50	21.47	60	132	27 L
29	59	5.32	—	21.80	23.19	60	96	46 L
30	60	5.00	9.82	—	—	60	119	3 R
31	66	5.86	—	—	—	0	—	—
32	67	6.95	14.74	18.29	19.61	0	197	3 R
33	68	5.74	15.41	20.43	21.66	0	193	9 L
34	69	5.12	14.46	19.69	20.59	0	173	2 R
35	70	4.72	13.23	18.74	20.87	0	167	9 L

\*R = right and L = left.

Table 4. AGBS design test of fixture vs. should fire

Group	Time to separation (sec.)	Time to ground (sec.)	Time to whistle (sec.)	Time to blast (sec.)	Range (meters)	Deflection <sup>a</sup> (meters)
Round ogive	5.56	9.07	15.98	18.08	291	13 R
30 g	6.52	--	17.74	18.55	170 <sup>b</sup>	30 R <sup>b</sup>
New payload	6.54	--	16.44	18.27	175 <sup>b</sup>	21 R <sup>b</sup>
Fixture fire	6.43	--	17.22	19.37	285	14 R
	5.87	9.37	17.00	18.96	289	15 R
					$\bar{x}^c$ $s^d$	288 3.06
						14 R 1.00
Flat ogive	6.80	--	17.40	19.37	216	23 R
30 g	6.87	8.69	16.84	18.20	215	21 R
New payload	6.93	8.59	17.19	18.75	196	21 R
Fixture fire	6.77	8.46	18.19	19.63	206	21 R
	6.93	8.38	16.94	18.39	216	18 R
					$\bar{x}^c$ $s^d$	210 8.79
						21 R 1.87
Flat ogive	6.59	8.27	16.91	19.03	216	17 R
30 g	6.33	8.97	16.27	18.25 <sup>e</sup>	220	21 R
Old payload	6.31	8.64	15.90	17.65	227	29 R
Fixture fire	6.73	10.12	18.45	20.17 <sup>e</sup>	208	18 R
	6.62	8.63	16.97	19.09	218	9 R
					$\bar{x}^c$ $s^d$	218 6.87
						19 R 7.22
Flat ogive	5.81	8.33	14.85	16.89	205	16 R
30 g	--	--	14.41	16.41	167	3 R
Old payload	4.97	--	14.62	16.20	181	21 L
Shoulder fire	Misfire - weapon malfunctioned					
	Misfire - weapon malfunctioned					
					$\bar{x}^c$ $s^d$	184 19.22
						0.67 L 18.77

<sup>a</sup>R = Right and L = Left.

<sup>b</sup>Ogive came off at launch. Data disregarded.

<sup>c</sup>Average range.

<sup>d</sup>Standard deviation.

<sup>e</sup>No blast.

Table 5. Range impact velocity and time of flight

Delay (sec.)	QE* (deg)	Payload			Projectile body		
		Range (meters)	Velocity (ft/sec.)	Time of flight (sec.)	Range (meters)	Velocity (ft/sec.)	Time of flight (sec.)
4	40	291	104	8.7	251	89	8.9
4	45	285	106	9.5	239	91	9.7
4	50	274	108	10.3	223	93	10.4
4	60	238	111	11.7	181	94	11.5
4	70	183	113	12.8	127	95	12.3
4	80	106	114	13.7	64	96	12.8
5	40	296	106	8.5	268	89	9.0
5	45	291	107	9.3	256	91	9.9
5	50	280	108	10.1	239	93	10.6
5	60	244	111	11.5	192	94	11.9
5	70	191	113	12.6	131	95	12.8
5	80	119	114	13.5	58	96	13.2
6	40	297	113	8.3	282	89	8.9
6	45	292	110	9.1	271	91	9.8
6	50	281	110	9.9	254	92	10.7
6	60	243	111	11.2	207	94	12.1
6	70	187	113	12.2	143	95	13.2
6	80	112	114	12.7	65	96	14.0
7	40	296	125	8.2	291	92	8.6
7	45	292	118	9.0	282	91	9.6
7	50	281	114	9.7	266	92	10.5
7	60	242	113	11.0	220	94	12.0
7	70	181	114	12.0	156	95	13.2
7	80	101	115	12.5	80	96	14.1
8	40	295	149	8.2	295	104	8.3
8	45	291	133	8.9	289	96	9.3
8	50	280	124	9.6	275	93	10.2
8	60	241	117	10.9	230	94	11.8
8	70	179	116	11.9	166	95	13.0
8	80	198	116	12.3	88	95	13.8
9	40	295	134	8.25	295	134	8.25
9	45	290	137	8.96	290	137	8.96
9	50	280	144	9.6	279	102	9.8
9	60	241	126	10.7	236	95	11.4
9	70	179	120	11.7	172	95	12.6
9	80	97	119	12.3	92	95	13.5

\*Quadrant elevation.

Table 6. Trajectory of the AGBS

Delay (sec.)	QE <sup>a</sup> (deg)	Payload			Projectile			
		Range (meters)	Impact Velocity (ft/sec.)	Time of flight (sec.)	Range (meters)	Impact velocity (ft/sec.)	Time of flight (sec.)	Impact angle (deg)
4	40	269	104	8.0	205	83	8.3	79
4	45	267	105	8.8	113	90	9.0	82
4	50	261	106	9.6	176	92	9.6	84
4	60	235	109	11.0	133	94	10.4	87
4	70	190	112	12.2	82	95	10.9	89 IA <sup>b</sup>
4	80	118	113	13.3	38	95	11.5	90 IA <sup>b</sup>
5	40	263	111	7.7	224	86	8.6	78
5	45	262	109	8.4	211	89	9.3	81
5	50	255	108	9.1	193	91	10.0	84
5	60	229	109	10.4	146	94	11.1	88
5	70	188	111	11.4	89	95	12.0	90
5	80	134	112	12.2	117	95	12.6	90
6	40	257	123	7.6	239	83	8.6	75
6	45	254	117	8.2	227	87	9.4	80
6	50	247	114	8.9	211	90	10.2	83
6	60	217	112	10.0	166	93	11.5	87
6	70	170	113	10.8	108	94	12.6	89
6	80	100	114	11.2	48	95	13.3	90
7	40	253	144	7.6	249	77	8.2	69
7	45	249	132	8.2	240	83	9.2	76
7	50	241	124	8.8	225	87	10.0	80
7	60	210	118	9.9	184	92	11.4	85
7	70	159	116	10.7	128	94	12.6	88
7	80	88	116	11.1	65	95	13.4	89
8	40	—	—	—	252	120	7.8	61 IB <sup>c</sup>
8	45	247	155	8.3	246	77	8.7	69
8	50	238	142	8.8	234	83	9.6	76
8	60	206	127	9.8	194	89	11.1	83
8	70	154	122	10.6	139	92	12.2	87
8	80	84	120	11.1	74	94	13.0	89
9	40	—	—	—	252	120	7.8	61 IB <sup>c</sup>
9	45	—	—	—	247	123	8.5	65 IB <sup>c</sup>
9	50	237	172	9.04	237	78	9.1	69
9	60	204	145	9.9	201	86	10.7	80
9	70	152	133	10.6	146	90	11.9	85
9	80	83	128	11.1	78	92	12.6	88

<sup>a</sup>Quadrant elevation.<sup>b</sup>Whistle functioning before impact.<sup>c</sup>Impact before ejection of payload.

Table 7. Range, impact velocity, and time of flight;  
non-functioning delay

<u>QE</u>	<u>Range (meters)</u>	<u>Time of flight (sec.)</u>	<u>Impact velocity (ft/sec.)</u>	<u>Impact angle (deg)</u>
40	252	7.8	120	61
45	247	8.5	123	65
50	237	9.1	126	69
60	203	10.1	131	75
70	151	10.9	135	80
80	82	11.4	137	85

---

\*Quadrant elevation



Table 8. Comparison of tested and computer impact velocities

EJECTION ROUNDS

<u>Launch angle (dry)</u>	<u>Type of round</u>	<u>Impact</u>	<u>Velocities</u>
		<u>Computed (ft/sec.)</u>	<u>Tested<sup>c</sup> (ft/sec.)</u>
40	FN <sup>a</sup>	123	110 (5)
40	RN <sup>b</sup>	125	122 (4)
50	FN <sup>a</sup>	114	113 (2)
50	RN <sup>b</sup>	114	127 (2)
80	FN <sup>a</sup>	114	118 (2)
80	RN <sup>b</sup>	115	115 (1)

NO EJECTION

<u>Launch angle (dry)</u>	<u>Type of round</u>	<u>Impact</u>	<u>Velocities</u>
		<u>Computed (ft/sec.)</u>	<u>Tested<sup>c</sup> (ft/sec.)</u>
40	FN <sup>a</sup>	134	121 (1)
40	RN <sup>b</sup>	134	139 (2)
50	RN <sup>b</sup>	140	145 (2)
50	FN <sup>a</sup>	140	133 (2)
80	RN <sup>b</sup>	152	142 (1)
80	FN <sup>a</sup>	152	150 (1)

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<sup>a</sup>Flat nose configuration.

<sup>b</sup>Round nose configuration.

<sup>c</sup>Velocities given as an average for the number of items in the parenthesis.

Table 9. Noise level of burst charge

<u>Distances (meters)</u>	<u>Noise level (db)</u>	<u>Average (db)</u>
50	139	135
	134	
	133	
35	138	138
	142	
	134	
25	140	142
	145	
	145	
	140	
	137	
	142	
	145	
20	141	146
	148	
	149	
15	150 +	150 +
	150	
	150 +	

Table 10. AGBS firing table, Ft. Carson

<u>QE*</u> <u>(deg)</u>	<u>Average</u> <u>range</u> <u>(meters)</u>	<u>Mean</u> <u>dispersion</u> <u>(meters)</u>
40	380	12.50
50	360	22.50
60	320	23.75
70	245	32.75
80	215	36.25

---

\*Quadrant elevation.

Table 11. AGBS test, Ft. Carson, dud rounds

UNMODIFIED

<u>Date</u>	<u>Number of rounds</u>	<u>Number of payload duds</u>
15 March 1978	42	9
16 March 1978	76	25
17 March 1978	58	6
20 March 1978	<u>104</u>	<u>16</u>
	280	56

20% Duds

MODIFIED

<u>Date</u>	<u>Number of rounds</u>	<u>Number of payload duds</u>
20 March 1978	64	6
21 March 1978	66	5
22 March 1978	<u>50</u>	<u>4</u>
	180	15

8.33% duds

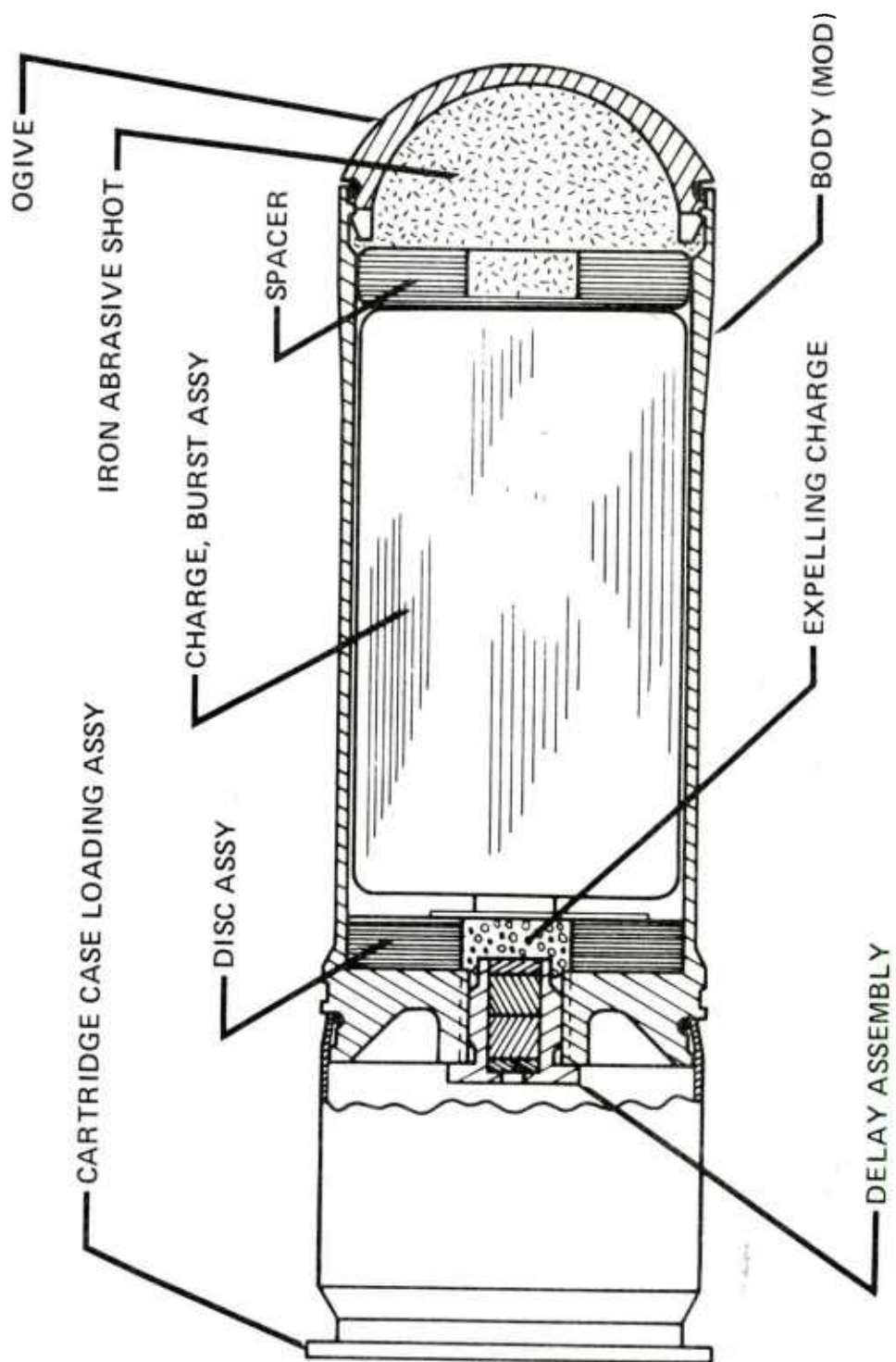


Figure 1. Artillery ground burst simulator.

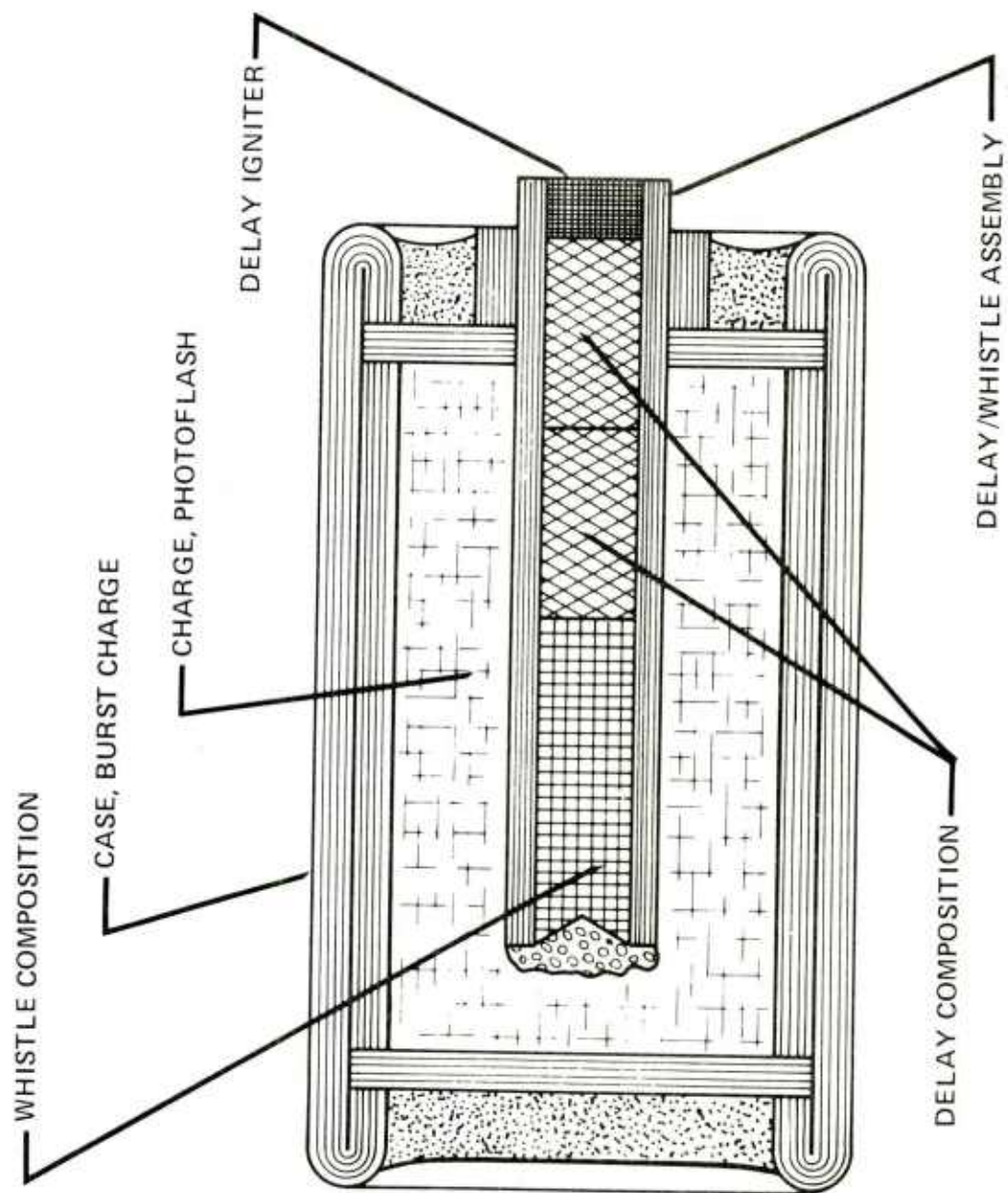


Figure 2. Burst charge assembly

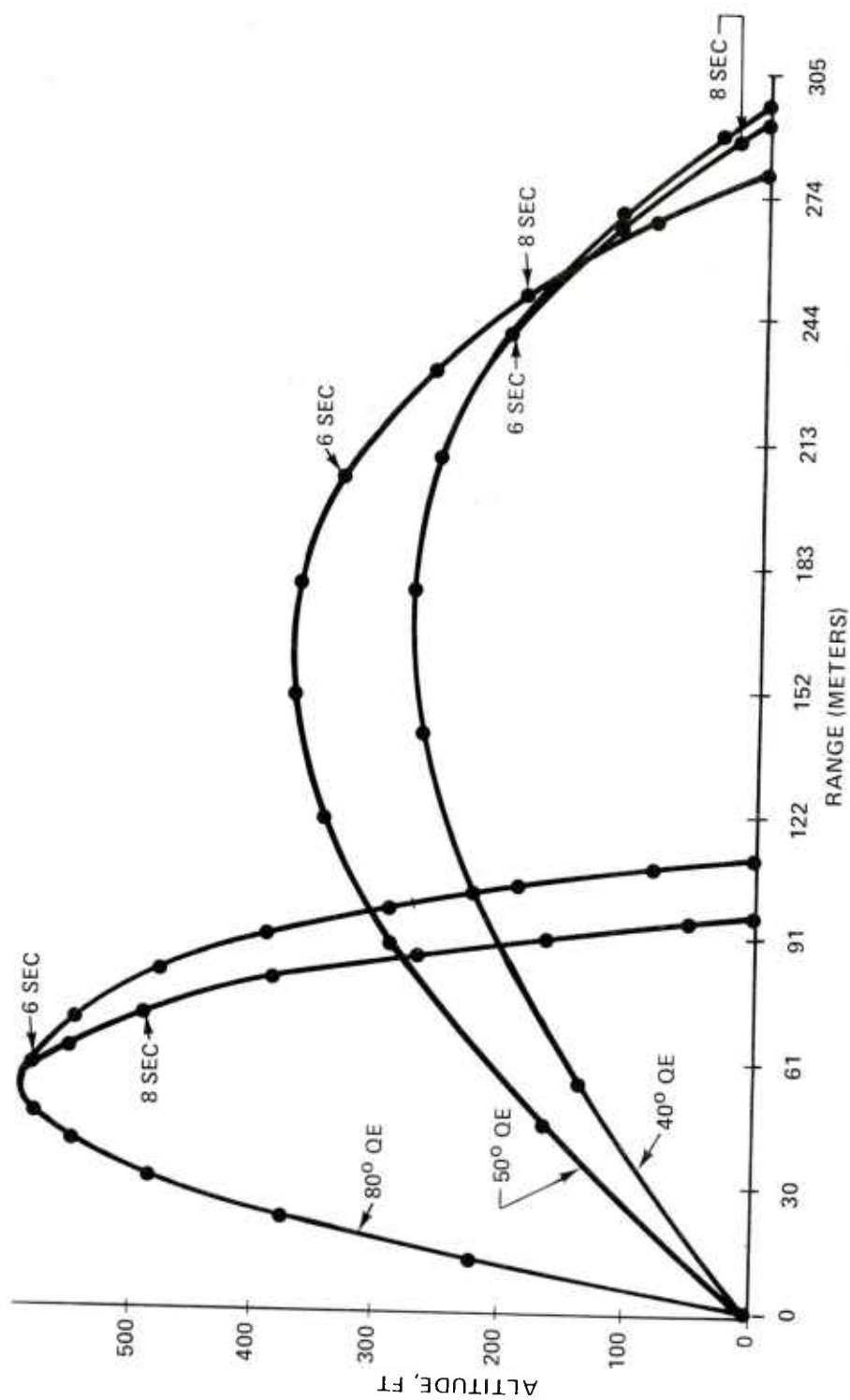


Figure 3. Trajectories of the artillery ground burst simulator.

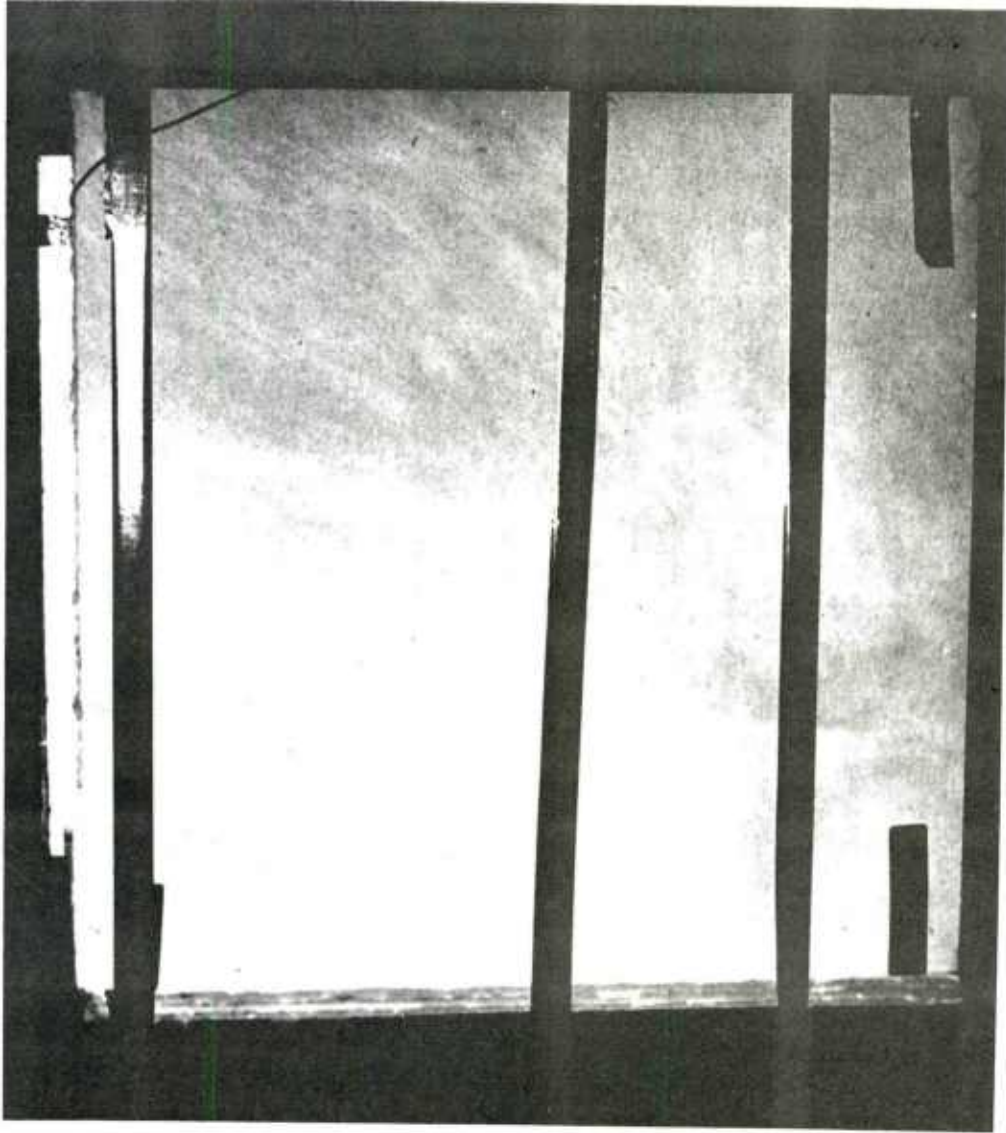


Figure 4. Fragmentation set-up.



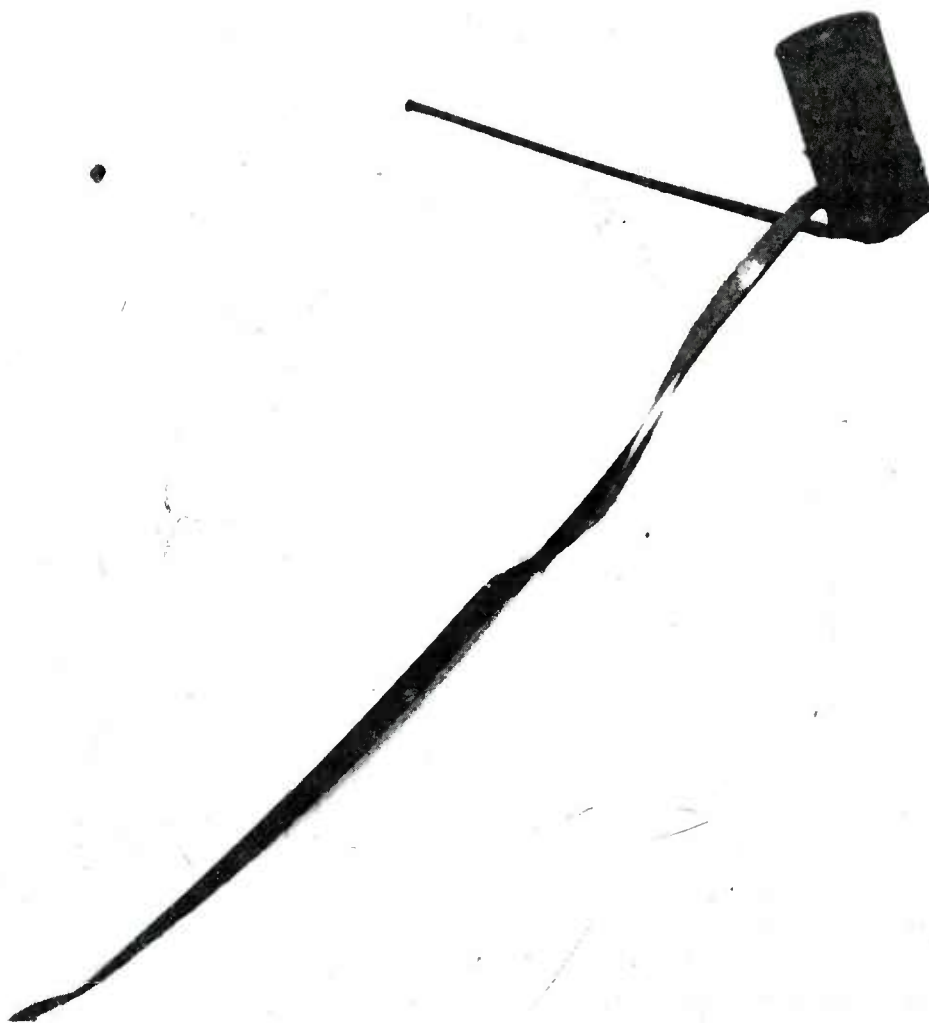


Figure 5. AGBS payload at bottom of test chamber.

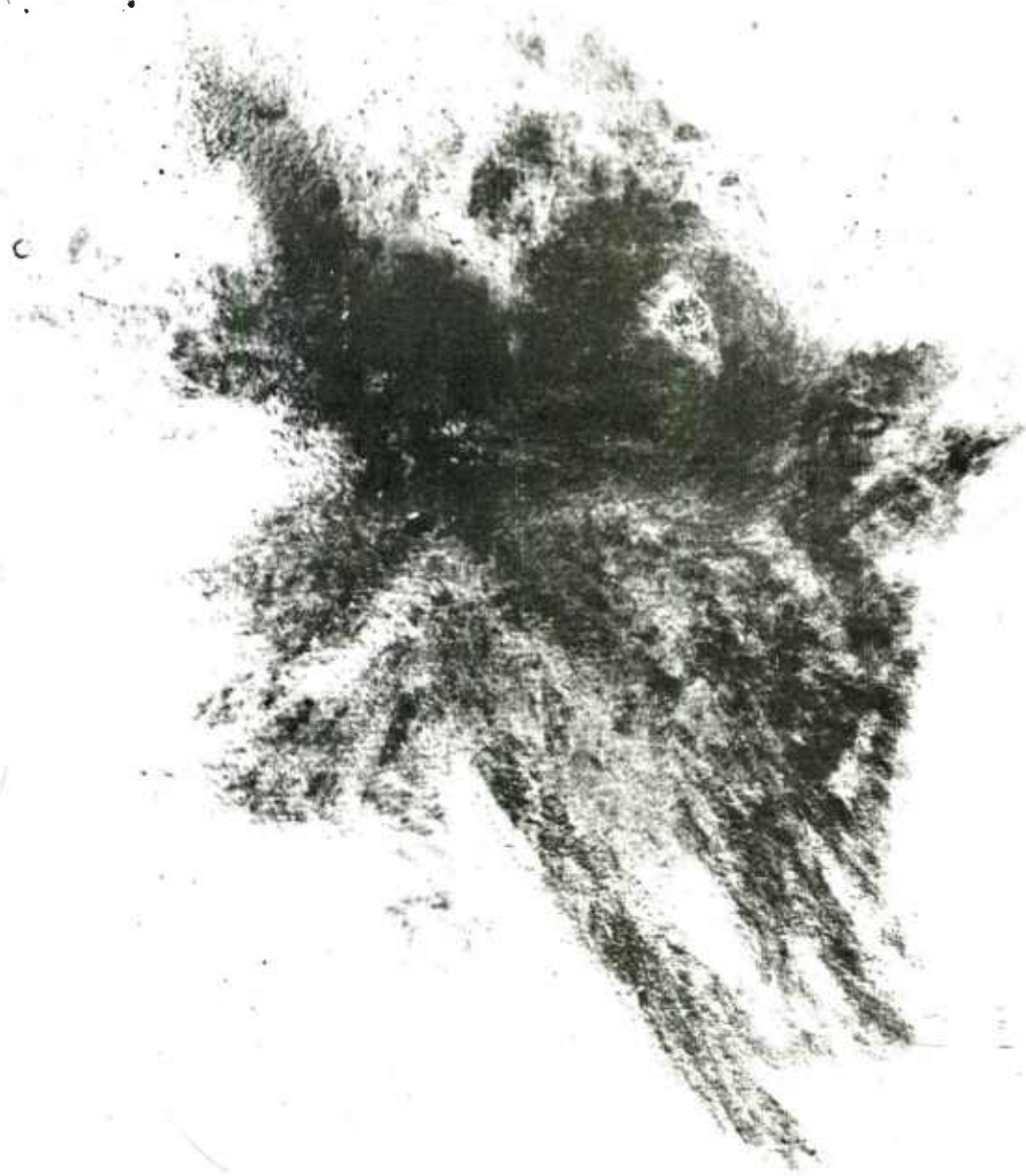


Figure 6. Bottom of test chamber after detonation.

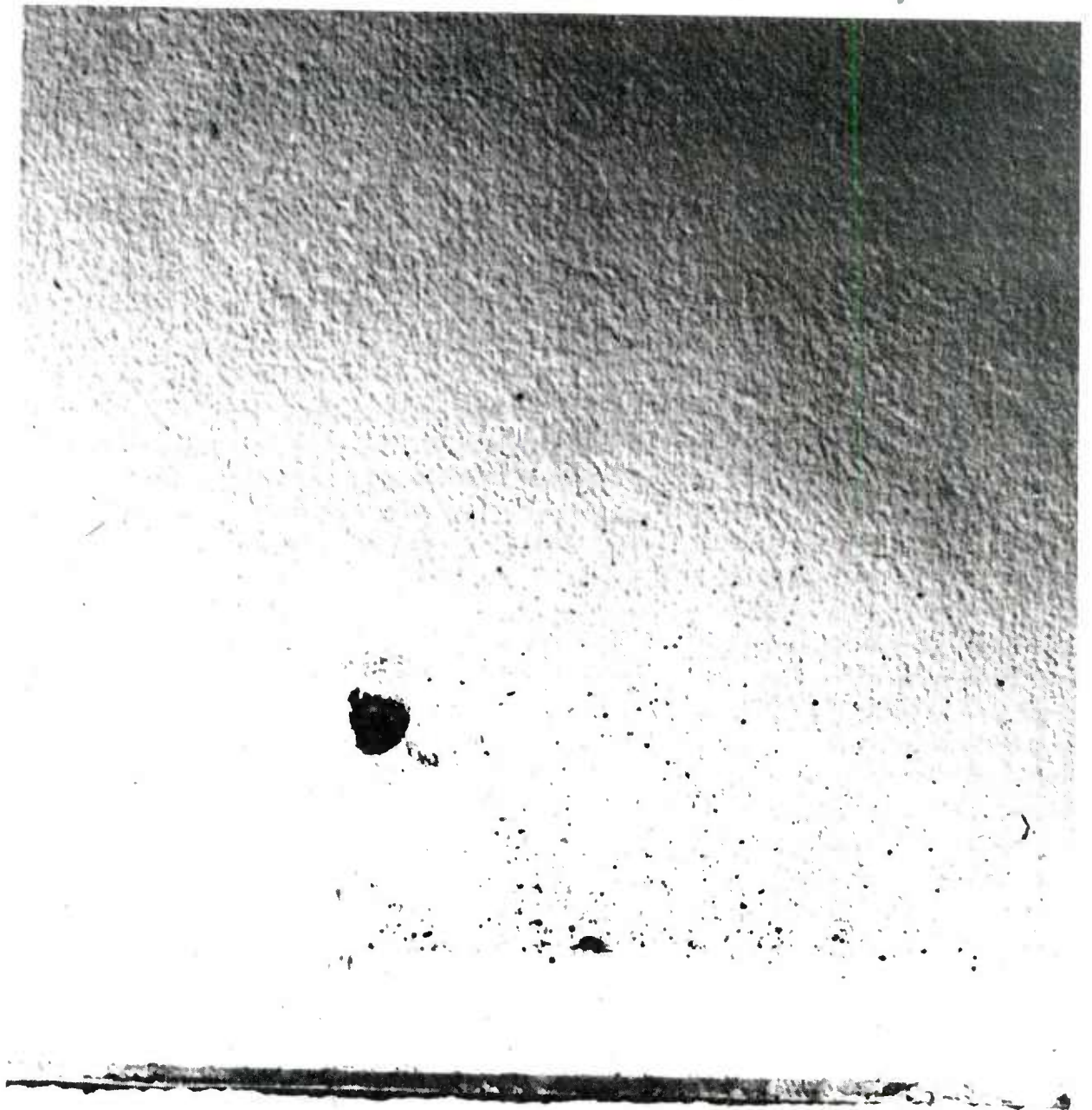


Figure 7. Penetration of side panel.



Figure 8. Delay/whistle assembly of side panel.

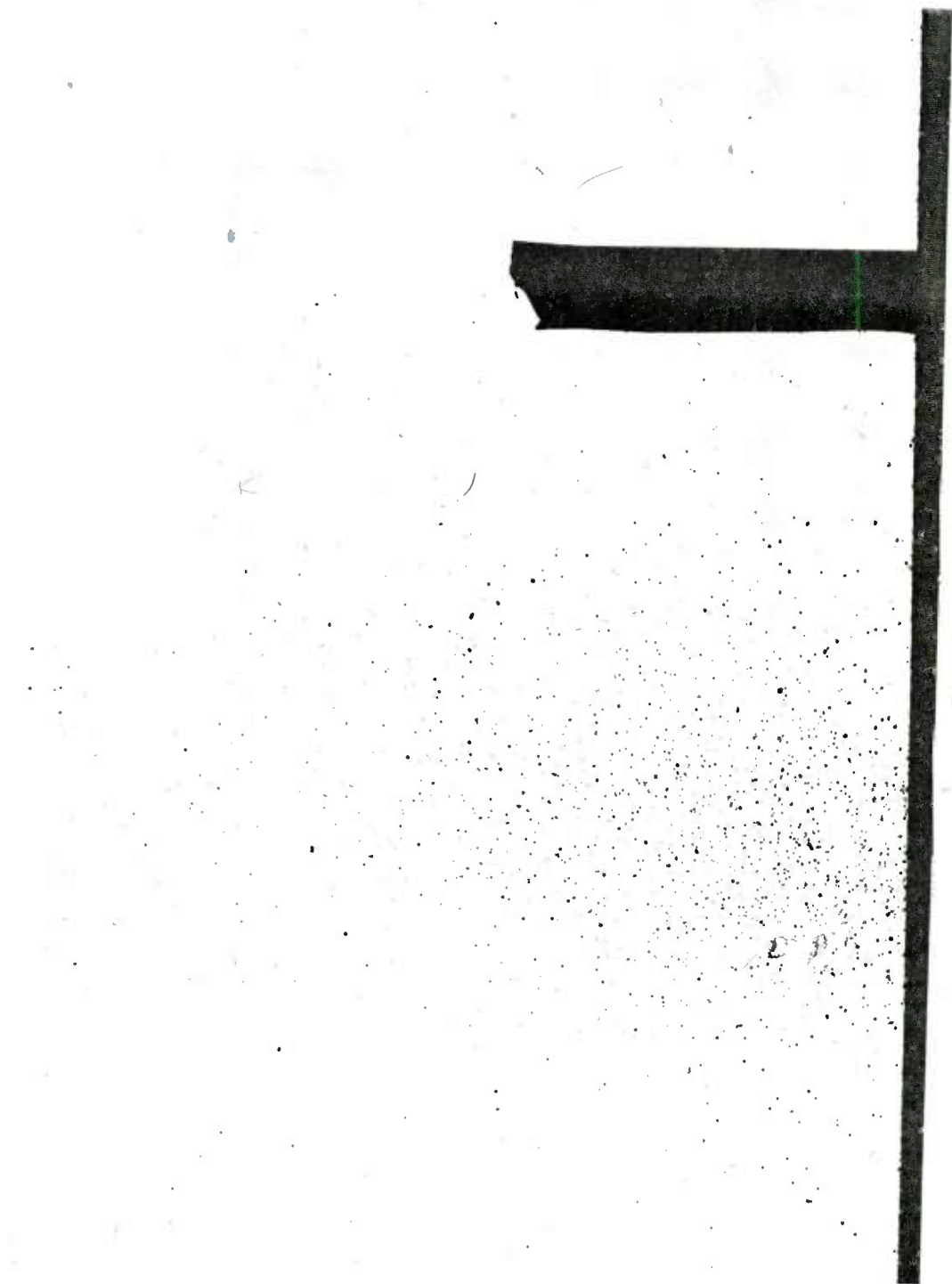


Figure 9. Powder marks on side panel.





Figure 10. Cardboard payload fragments.

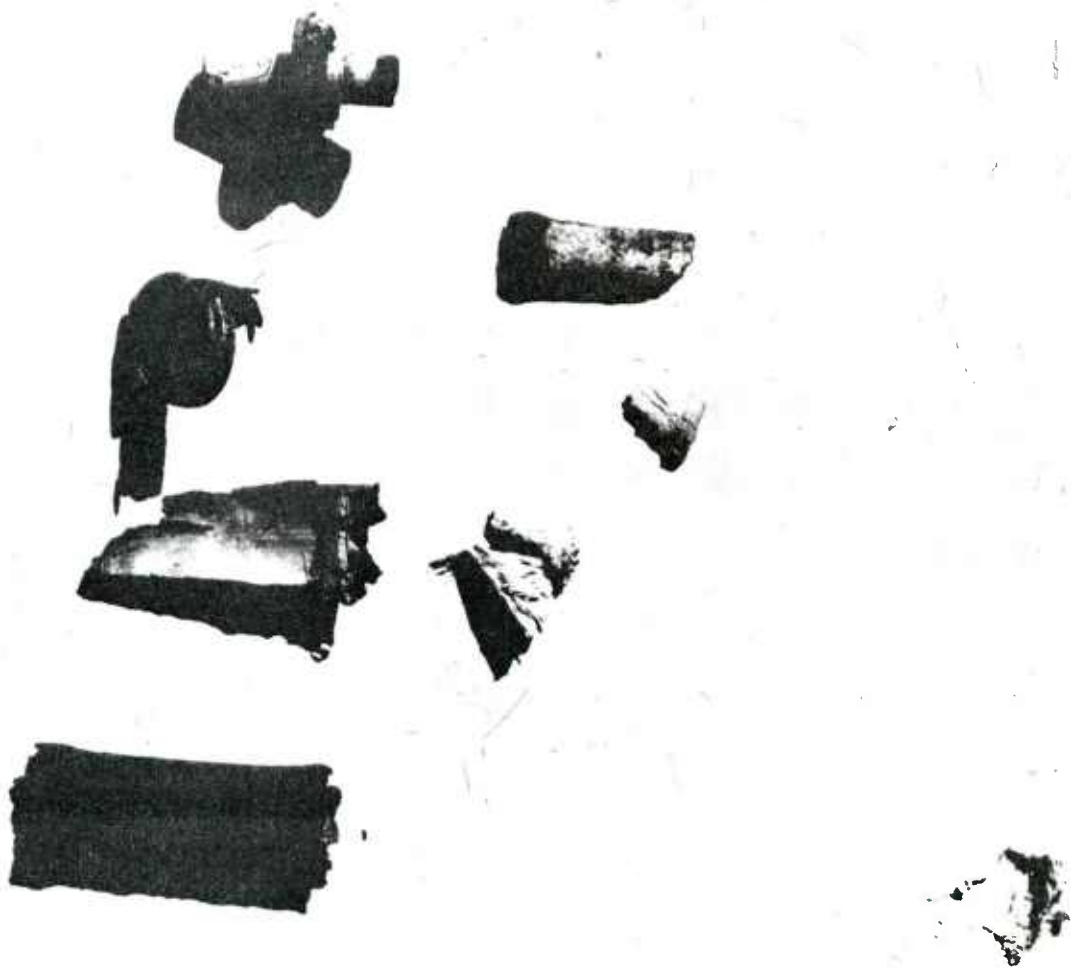


Figure 11. Cardboard payload fragments.

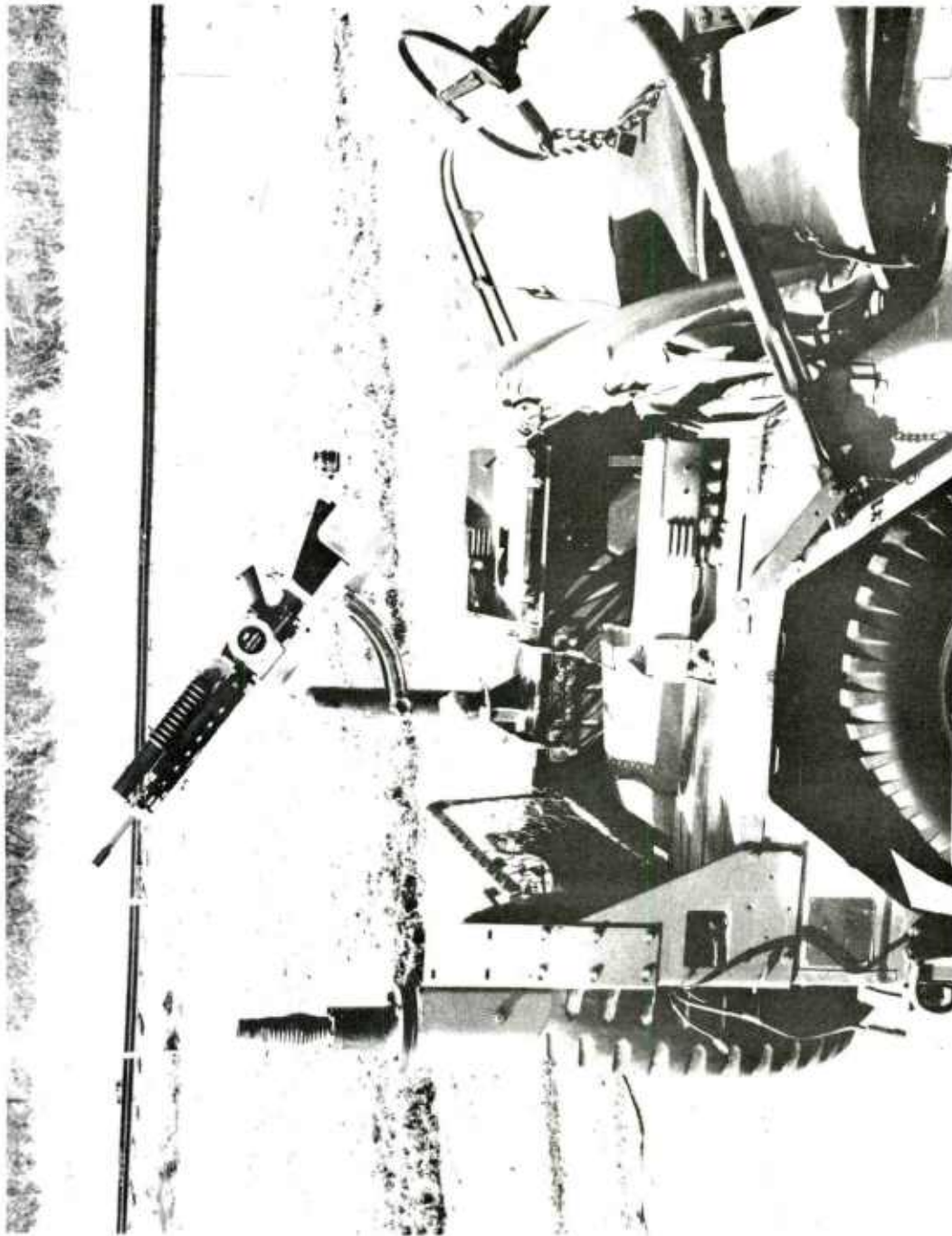


Figure 12. Launcher mounts.



## APPENDIX

### HAZARD STUDY OF THE 40 MM AGBS

## SUMMARY

A prototype Artillery Ground Burst Simulator (AGBS) 40 mm training round was evaluated for potential hazard to friendly troops. The analysis, including FORTRAN programs, is presented in this report. The evaluation was generated to provide early guidance to ARRADCOM design engineers during exploration development as well as for concept feasibility testing during the combined ARMS REALTRAIN Test.

The basic lethality probability (Pk) for the AGBS 40 mm round is shown in table I for various firing angles (QE) as well as for various modeled body types.

The probability of being struck by a dud round (not separated from its aluminum body) is given in table II. The probability of being struck at the terminal range by payload is shown in tables III, IV, and V for various delay times. The probability of being struck by the aluminum component body down range is shown in tables VI, VII, and VIII for various delay times.

The probability of being struck by payload during "battlefield simulation" exercises is shown in table IX. Here, a model is utilized of various battlefield sizes and progressive reductions in number of personnel involved simulating battle conditions.

These analyses indicate blunt trauma injury hazards but no significant penetration hazards to troops during training engagements. The greater hazard is found to be injury from being hit by a dud round.

## BACKGROUND

The Artillery Ground Burst Simulator, AGBS, is a training device fired into friendly troop areas, simulating visual and audio bursts of an artillery round. The firing of live ammunition over and into friendly troop areas is unprecedented. The analysis and evaluation of the AGBS round was required on a concurrent basis during the early developmental phases. The overall objectives of this study are: (1) to provide the methodology for future hazard assessments of training rounds; (2) to calculate the hit probabilities of the round; and (3) to discuss their injury implications.

Injury possibilities were considered: (a) for blunt trauma describing effects where the wounding mechanism is a blunt crushing or contusion of tissue, and (b) for penetration describing effects from a cutting or penetrating mechanism. Existing Edgewood Arsenal models and data bases (ref. 1) were utilized to provide timely analysis. The models were designed to evaluate blunt trauma induced by metallic bullets (ref. 1) resulting in death and to estimate penetration injuries for compact steel fragments (ref. 2) not necessarily causing death. Since the training round is a different material and of larger size than a compact steel fragment or bullet, these criteria may not strictly apply. However, they are a strong indicator of hazard of the round and are the best information to work with in lieu of a more specialized data base.

## METHODOLOGY & INPUT PARAMETERS

An appraisal of blunt trauma and penetration hazards for the training round was performed. The assessment was divided into two parts:

- a. Given a hit, what is the hazard condition due to penetration injuries?
- b. Given a hit, what is the hazard condition due to blunt trauma?

Given that a man is hit, injury caused by penetration is considered first. A modified penetration test was performed wherein a round is ignited inside a four foot cube of  $\frac{1}{2}$  inch thick Celotex witness panels. The resultant debris was collected for analysis; and panel penetration, if any, by fragments was determined.

To estimate blunt trauma probabilities, a computer program AGBS (for Artillery Ground Burst Simulator) was developed. Program AGBS is based in part on Sturdivan's Improved Blunt Trauma Report (Ref. 1) and calculates lethality probability at the abdomen (liver), PLIVER, and at the thorax (lung) site, PLUNG. The probability of lethality in each case is a function of a dose measure, "X", Table A. This method, where the dose "X" is calculated as

$$MV^2/W^{1/3}TD$$

has provided an acceptable predictive model for large animal, and hence, human lethality.

TABLE A

Model of Human Lethality, "X"  
From Ref (1)

$$X = \frac{MV^2}{W^{1/3}TD}$$

M = Mass of projectile  
V = Velocity of projectile  
D = Diameter of projectile  
W = Mass of Soldier  
T = Thickness of body wall over vulnerable organ

At the lung site, probability of lethality, PLUNG, is calculated as

$$PLUNG = \frac{1}{1+G}$$

where  $G = e^{\alpha + \beta \ln x}$

Similarly, the probability of lethality at the liver site, PLIVER, is calculated as

$$PLIVER = \frac{1}{1+H}$$

where  $H = e^{\alpha + \beta \ln x}$

TABLE B

Coefficients for the Logistic Function of Lethality Probability  
Ref (1)

<u>LUNG</u>	<u>LIVER</u>
= 34.13	= 65.23
= 3.597	= -6.847

The ultimate lethality at a body site, PDLUNG (for example), from exactly one hit with a dud projectile is given by:

$$PDLUNG = N_r P(1-P)^{N_r-1}$$

where  $P = (ALUNG) (PLUNG)$

ALUNG is the probability of injury from a DUD at LUNG site and is calculated as

$$ALUNG = \frac{n a_{plu}}{A_{cep}} PDUD$$

where  $n = 3$ , number of troops in  $A_{cep}$

$A_{plu}$  = presented area of thorax (lung) or .0670 square meters

$A_{cep}$  = area occupied by  $n$  troops or 1963.5 square meters Ref (4)

$N_r$  = number of rounds fired

PDUD = known dud rate of round (in this case  $9 \times 10^{-4}$ )

In the computer program AGBS, ALUNG and ALIVER are "read in" as data values ALUNG = 0.092131 and ALIVER = 0.075355.

For convenience, the receiptrocal of PDLUNG and PDLIVER, IDLUNG and IDLIVER, is also calculated in the computer program since it represents the frequency of occurrence of the event.

To estimate the probability of being hit by either payload or aluminum component body, a similar calculation is carried out. (See Math Formulation.)

A second computer program, Program BAT, (see Appendix) was developed to simulate a battle training situation and estimate the probability of a hit during engagements. The training scenario, Ref (4), as utilized is that there should be no more than three soldiers at any time within a 25 meter CEP, all troops are assumed to have an "average" exposure of 3000 sq cm body area.

Four cases are simulated. First, the beginning engagement is defined as "FULL BAT" of 120 troops deployed with 100 rounds fired uniformly into a full battlefield of 2KM x 5 KM. Next, we consider the "1/2 BAT" case with 10% less troops (108 troops) with 100 rounds fired uniformly into a reduced battlefield of 1/2 the original area. Then the third case of "1/4 BAT" is considered with 3/4 of the troops remaining (90 troops) with 100 rounds fired uniformly into 1/4 of the original battlefield area. Finally, the "1/8 BAT" end case is run with 1/2 the troops remaining (60 troops) with 100 rounds fired uniformly into 1/8 the original battlefield area. In each case the computer program "BAT" calculates the probability of one hit or at least one hit in the specified battlefield. One hundred rounds are considered to be available at all times.

### MATHEMATICAL FORMULATION

In this section the mathematical techniques used are explained.

In each case the binomial model is used for the computation of the probabilities of interest, i.e.,

$$P \text{ \{exactly 1 hit\} } = N_r P(1-P)^{N_r - 1}$$

and,

$$P \text{ \{at least 1 hit\} } = 1 - (1-P)^{N_r}$$

The parameter P is determined by the kind of hit. There are four kinds of hits considered:

- (1) Hit with a payload.
- (2) Hit with a dud.
- (3) Lethal hit with a dud in lung area.
- (4) Lethal hit with a dud in liver area.

For each of the above cases we have:

- (1)  $P = nA_p/A_{cep}$
- (2)  $P = (nA_p/A_{cep}) PDUD$

$$(3) P = (nA_{\text{plu}}/A_{\text{cep}}) \text{ PDUD PLUNG}$$

$$(4) P = (nA_{\text{pli}}/A_{\text{cep}}) \text{ PDUD PLIVER}$$

where,

$A_{\text{cep}}$  = area occupied by troops (computed from troop density of 3 troops/1964 m<sup>2</sup>).

$n$  = number of troops in area  $A_{\text{cep}}$ .

$A_{\text{p}}$  = presented area of individual soldier.

$A_{\text{plu}}$  = presented area of lung area.

$A_{\text{pli}}$  = presented area of liver area.

$N_r$  = total number of rounds fired.

PDUD = probability the round is a dud.

For example,

$$P \text{ \{exactly 1 hit of type 3\} } = N_r P(1-P)^{N_r-1}$$

where,

$$P = (n(A_{\text{plu}})/A_{\text{cep}}) \text{ PDUD PLUNG}$$

Some of the computations have been simplified by using the Poisson approximation to the binomial, i.e.,

$$P \text{ \{exactly } k \text{ hits\} } = \binom{N_r}{k} P^k (1-P)^{N_r-k} \sim e^{-N_r P} \frac{(N_r P)^k}{k!}$$

For  $k = 1$  we have:

$$P \text{ \{exactly 1 hit\} } \sim N_r P e^{-N_r P}$$

## LETHALITY RESULTS

### Blunt Trauma Lethality Results

In Table I the basic lethality of the AGBS projectile is shown for three typical soldier weights: a) 55kg weight (or 120 lb) and a thin body wall of 2cm; b) 75kg weight (or 165 lb) and a body wall of 3cm; and c) 95kg weight (or 210 lb) and a body wall of 4cm. Pk Lung and Pk Liver are lethality probabilities assuming a hit in the thorax or abdomen regions. The greater lethality probabilities are for the lung area and for the "lightweight" soldier and increase with projectile velocity.

In Table II, the dud hit probability for lethality is introduced. The same relationships hold as in the direct hit lethality (Table I) cases.

In Tables III, IV, and V, lethality probabilities of a 52gm payload are presented for various delay times. Again the lethality exhibit the same relationships of greater lethality for the lightweight soldier, for the lung area, and increase with velocity. However, here the lower weight and velocities for the payload vs the total projectile cut the lethality probability down by a factor of approximately 100 for the lung area.

In Tables VI, VII, and VIII lethality probabilities for a 51gm aluminum carrier are presented. Lethalities here are lowest of the total family due to lowest velocities and weight of the carrier.

A war game study, called Program "BAT", is illustrated in Table IX for probabilities of being struck by either a payload at the terminal range or by the aluminum body down range. The risks appear limited and most injuries would probably be contusions or less based upon an independent APG study with similar configurations (Ref 5).

In Table X, a comparison of calculated hit probabilities is illustrated by exactly one hit vs at least one hit. In the case where a dud round is considered, there is no discernable difference. In the case of a payload, the difference is of a 2% magnitude, well within the experimental errors of the data bank of the original Edgewood Arsenal reference model (Ref 1). In addition, the probabilities of lethality based upon exactly one and at least one hit are shown. Again the difference is of an insignificant magnitude, 1.38%, as compared to the original data base.



Because the probability of at least one hit and the probability of exactly one hit are extremely close, it may be concluded that the probability of more than one hit is near zero; i.e., the chance of hitting 2 or more soldiers is insignificant. Hence, all calculated values in all tables (other than Table X) are derived from probabilities for exactly one hit.

#### Penetration Lethality Results

Debris from fired rounds essentially consisted of pressed cardboard fragments of no penetrating quality. The only instance of panel penetration was from the delay-whistle tube. This tube is a lighter version of the M115 whistle tube and weighs 6 grams. For comparison purposes, the M115 tube assembly weighs 12 grams and has never been reported as presenting fragmentation hazards. Further, there is prior experimental evidence that it requires 20gm of a plastic like material to cause skin penetration (Ref 3).

The foregoing data and conclusion were presented to the Army Surgeon General's Office with other information as a Interim Safety Statement. Their acceptance permitted the AGBS, 40mm round to be utilized on a limited scale with no injury reports, during the March 78 REALTRAIN TEST at Ft. Carson, CO.

#### CONCLUSION

Based upon the utility shown by this study it is recommended that future programs for training round development include a Safety Program Plan, see Table XI.

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TABLE I  
LETHALITY OF AGBS 40 MM  
PROJECTILE = 140 GM

SOLDIER WGT/THICK (KG/CM)	QE (DEG)	VEL (M/S)	PK LUNG	PK LIVER
55/2.	40.	36.58	.0603900	.0041232
	45.	37.49	.0712354	.0057631
	50.	38.40	.0835295	.0079857
	60.	39.93	.1077188	.0135590
	70.	41.15	.1303637	.0203340
	80.	41.76	.1428415	.0247611
75/3.	40.	36.58	.0102014	.0001270
	45.	37.49	.0121500	.0001778
	50.	38.40	.0144051	.0002469
	60.	39.93	.0189915	.0004216
	70.	41.15	.0234746	.0006364
	80.	41.76	.0260277	.0007784
95/4.	40.	36.58	.0027506	.0000103
	45.	37.49	.0032807	.0000145
	50.	38.40	.0038961	.0000201
	60.	39.93	.0051540	.0000343
	70.	41.15	.0063920	.0000518
	80.	41.76	.0071006	.0000633

TABLE II  
LETHALITY OF AGBS 40 MM  
PROJECTILE = 140.GM

SOLDIER WGT/THICK (KG/CM)	QE (DEG)	VEL (M/S)	PD LUNG	PD LIVER	FD LUNG	FD LIVER
55./2.						
	40.	36.58	.00000032	.0000000301	.312E+07	.332E+08
	45.	37.49	.00000034	.0000000416	.292E+07	.240E+08
	50.	38.40	.00000036	.0000000567	.279E+07	.176E+08
	60.	39.93	.00000037	.0000000923	.270E+07	.108E+08
	70.	41.15	.00000036	.0000001316	.275E+07	.760E+07
	80.	41.76	.00000035	.0000001551	.282E+07	.645E+07
75./3.						
	40.	36.58	.00000009	.0000000010	.117E+08	.105E+10
	45.	37.49	.00000010	.0000000013	.998E+07	.747E+09
	50.	38.40	.00000012	.0000000019	.859E+07	.538E+09
	60.	39.93	.00000015	.0000000032	.680E+07	.316E+09
	70.	41.15	.00000017	.0000000048	.573E+07	.210E+09
	80.	41.76	.00000019	.0000000058	.529E+07	.171E+09
95./4						
	40.	36.58	.00000002	.0000000001	.405E+08	.128E+11
	45.	37.49	.00000003	.0000000001	.341E+08	.918E+10
	50.	38.40	.00000003	.0000000002	.289E+08	.661E+10
	60.	39.93	.00000005	.0000000003	.221E+08	.387E+10
	70.	41.15	.00000006	.0000000004	.180E+08	.256E+10
	80.	41.76	.00000006	.0000000005	.163E+08	.210E+10

TABLE III  
LETHALITY OF AGBS 40 MM  
PROJECTILE = 52. GM  
DELAY TIME = 5. SEC

SOLDIER WGT/THICK (KG/CM)	QE (DEG)	VEL (M/S)	PK LUNG	PK LIVER
55./2.				
	40.	33.80	.0010315	.0000016
	45.	33.20	.0009069	.0000012
	50.	32.90	.0008496	.0000011
	60.	33.20	.0009069	.0000012
	70.	33.80	.0010315	.0000016
	80.	34.10	.0010991	.0000018
75./3.				
	40.	33.80	.0001656	.0000000
	45.	33.20	.0001455	.0000000
	50.	32.90	.0001363	.0000000
	60.	33.20	.0001455	.0000000
	70.	33.80	.0001656	.0000000
	80.	34.10	.0001764	.0000001
95./4.				
	40.	33.80	.0000443	.0000000
	45.	33.20	.0000390	.0000000
	50.	32.90	.0000365	.0000000
	60.	33.20	.0000390	.0000000
	70.	33.80	.0000443	.0000000
	80.	34.10	.0000472	.0000000

TABLE IV  
LETHALITY OF AGBS 40 MM

PROJECTILE = 52. GM

DELAY TIME = 6. SEC

SOLDIER WGT/THICK (KG/CM)	QE (DEG)	VEL (M/S)	PK LUNG	PK LIVER
55./2.	40.	37.50	.0021753	.0000066
	45.	35.70	.0015280	.0000034
	50.	34.70	.0012459	.0000023
	60.	34.10	.0010991	.0000018
	70.	34.40	.0011705	.0000020
	80.	34.70	.0012459	.0000023
75./3.	40.	37.50	.0003495	.0000002
	45.	35.70	.0002453	.0000001
	50.	34.70	.0002000	.0000001
	60.	34.10	.0001764	.0000001
	70.	34.40	.0001879	.0000001
	80.	34.70	.0002000	.0000001
95./4.	40.	37.50	.0000935	.0000000
	45.	35.70	.0000657	.0000000
	50.	34.70	.0000535	.0000000
	60.	34.10	.0000472	.0000000
	70.	34.40	.0000503	.0000000
	80.	34.70	.0000535	.0000000

TABLE V

LETHALITY OF AGBS 40 MM

PROJECTILE = 52. GM

DELAY TIME = 7. SEC

SOLDIER WGT/THICK (KG/CM)	QE (DEG)	VEL (M/S)	PK LUNG	PK LIVER
55./2.	40.	43.90	.0067273	.0000571
	45.	40.20	.0035820	.0000171
	50.	37.80	.0023033	.0000074
	60.	36.00	.0016226	.0000038
	70.	35.40	.0014381	.0000030
	80.	35.40	.0014381	.0000030
75./3.	40.	43.90	.0010849	.0000018
	45.	40.20	.0005761	.0000005
	50.	37.80	.0003701	.0000002
	60.	36.00	.0002606	.0000001
	70.	35.40	.0002309	.0000001
	80.	35.40	.0002309	.0000001
95./4.	40.	43.90	.0002906	.0000001
	45.	40.20	.0001542	.0000000
	50.	37.80	.0000991	.0000000
	60.	36.00	.0000697	.0000000
	70.	35.40	.0000618	.0000000
	80.	35.40	.0000618	.0000000

TABLE VIII

## LETHALITY OF AGBS 40 MM

PROJECTILE = 51. GM

DELAY TIME = 7. SEC

SOLDIER WGT/THICK (KG/CM)	QE (DEG)	VEL (M/S)	PK LJNG	PK LIVER
55./2.	40.	23.50	.0000705	.0000000
	45.	25.30	.0001198	.0000000
	50.	26.50	.0001672	.0000000
	60.	28.00	.0002485	.0000001
	70.	28.70	.0002968	.0000001
	80.	29.00	.0003198	.0000002
75./3.	40.	23.50	.0000113	.0000000
	45.	25.30	.0000192	.0000000
	50.	26.50	.0000268	.0000000
	60.	28.00	.0000399	.0000000
	70.	28.70	.0000476	.0000000
	80.	29.00	.0000513	.0000000
95./4.	40.	23.50	.0000030	.0000000
	45.	25.30	.0000051	.0000000
	50.	26.50	.0000072	.0000000
	60.	28.00	.0000107	.0000000
	70.	28.70	.0000127	.0000000
	80.	29.00	.0000137	.0000000



TABLE IX

BATTLEFIELD (BAT) SIMULATION  
 PH= PROR OF ONE HIT INTO BAT

## FULL BAT

P =	.000164	PH =	.000164
P =	.000129	PH =	.000293
P =	.000051	PH =	.000343
P =	.000013	PH =	.000357
P =	.000003	PH =	.000359
P =	.000000	PH =	.000360
P =	.000000	PH =	.000360
P =	.000000	PH =	.000360
P =	.000000	PH =	.000360
P =	.000000	PH =	.000360

## HALF BAT

P =	.000157	PH =	.000157
P =	.000222	PH =	.000380
P =	.000157	PH =	.000537
P =	.000074	PH =	.000611
P =	.000026	PH =	.000637
P =	.000007	PH =	.000645
P =	.000002	PH =	.000646
P =	.000000	PH =	.000647
P =	.000000	PH =	.000647
P =	.000000	PH =	.000647

## QRT BAT

P =	.000102	PH =	.000102
P =	.000241	PH =	.000343
P =	.000284	PH =	.000627
P =	.000223	PH =	.000849
P =	.000131	PH =	.000980
P =	.000062	PH =	.001042
P =	.000024	PH =	.001066
P =	.000008	PH =	.001075
P =	.000002	PH =	.001077
P =	.000001	PH =	.001078

## EIGHT BAT

P =	.000062	PH =	.000062
P =	.000195	PH =	.000257
P =	.000306	PH =	.000564
P =	.000321	PH =	.000884
P =	.000252	PH =	.001136
P =	.000158	PH =	.001294
P =	.000083	PH =	.001377
P =	.000037	PH =	.001414
P =	.000015	PH =	.001429
P =	.000005	PH =	.001434

TABLE X

COMPARISON OF PROBABILITY OF EXACTLY  
1 HIT VS PROBABILITY OF AT LEAST  
1 HIT\*

<u>Case</u>	<u>P Hit</u>
Exactly 1 Hit With Payload	.04082
At Least 1 Hit With Payload	.04169
Exactly 1 Hit With Dud	.000038323
At Least 1 Hit With Dud	.000038323

COMPARISON FOR PROBABILITY OF LETHALITY

<u>Case</u>	<u>P Lethality</u>
Exactly 1 Hit With Dud	.00003833
At Least 1 Hit With Dud	.00003886

\*See Math Techniques Section for formulas

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